Prompt Photon Production and Observation of Deeply Virtual Compton Scattering

P R B Saull[1]
for the ZEUS Collaboration

[1] Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, 22603 Hamburg, Germany
E-mail: `patrick.saull@desy.de`

Abstract
Two recent results in ep physics using the ZEUS detector at HERA are discussed: a measurement of the prompt photon production cross section in photoproduction, and the first observation of Deeply Virtual Compton Scattering in DIS.

1. Introduction

Two types of real photon production processes in e^+p collisions which are currently studied using the ZEUS detector at HERA are prompt-γ production in photoproduction (γp) and Deeply Virtual Compton Scattering (DVCS) in deep inelastic scattering (DIS).

Prompt-γ production in γp interactions is the production of a real γ directly from the hard interaction of a quasi-real γ (invariant mass $Q^2 \approx 0$ ‡) with the proton. At leading order, two kinds of γp processes can be defined: direct, where the γ participates entirely in the hard interaction, and resolved, where the γ first fluctuates into a hadronic system and a parton from this system then enters into the hard interaction. Examples are depicted in Fig. 1. Prompt-γ production is less influenced by

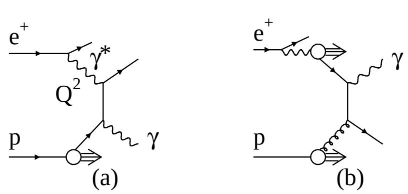

Figure 1. Examples of (a) direct and (b) resolved prompt-γ production at leading order in ep collisions.

hadronisation effects than, e.g., dijet production, although its production rate is down by a factor α/α_S in comparison. It is interesting because of its sensitivity to the parton density of the γ. The measurements can also be used to test next-to-leading order (NLO) perturbative QCD (pQCD).

‡ $Q^2 = -(e - e')^2$, where e and e' are the initial and final positron four-momenta, respectively.

DVCS [1], depicted in Fig. 2, is the hard diffractive scattering of a γ off a proton, $e^+p \rightarrow e^+\gamma p$. This is a process which has never been seen before at high energies, but which is predicted by FFS [2] to have a fairly high counting rate. DVCS

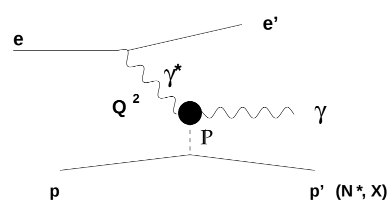

Figure 2. Diagram for DVCS.

is an exciting process because of its potential for accessing the skewed parton distributions (SPD's) of the proton. SPD's, which quantify two-particle correlations in the proton, are a generalisation of the usual proton parton distributions to the case where the squared momentum transfer to the proton is non-zero. The advantage of DVCS over processes where a hadron is diffractively produced is two-fold: the theoretical uncertainty in the hadronic wave function is avoided, and the DVCS rate is predicted to be less suppressed by a factor of Q^2 [3]. Furthermore, its final state is identical to that of QED Compton scattering (QEDC), and interference of the two processes potentially allows the measurement of the real part of a QCD amplitude.

A common feature of these two studies at ZEUS is that each involves the detection of a γ in the

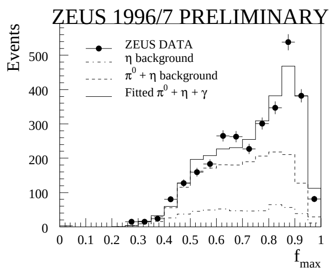

Figure 3. f_{max} distribution for prompt-γ candidates.

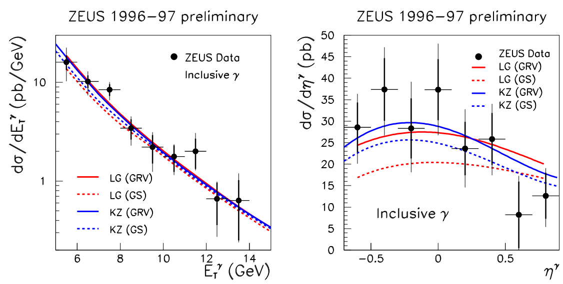

Figure 4. Prompt-γ cross sections as a function of E_T^γ and η^γ, with NLO predictions overlaid.

barrel part of the calorimeter (BCAL), which has its electromagnetic (EM) section segmented into 5×20 cm^2 cells. A potential background contribution to γ candidates, i.e. those tagged EM clusters not associated with a track in the central tracking detector, arises from π^0 and η production. However, these particles tend to produce broader clusters in the BCAL than single γ's. Two shower shape variables [4] are employed to exploit this difference: Z_{width}, which is the energy-weighted average of the width of the EM cluster in the Z-direction § (the direction in which the BCAL is most finely segmented); and f_{max}, which is the fraction of the EM cluster energy carried by the most energetic cell in the cluster.

2. Prompt Photon Production

The f_{max} distribution for the 1996/97 prompt-γ photoproduction analysis [5] is shown in Fig. 3. Overlaid are the expected contributions from η, π^0, and γ. A γ signal at high f_{max} values is evident. The prompt-γ production cross section for γ transverse energies $E_T^\gamma > 5$ GeV and γ rapidity interval $-0.7 \leq \eta^\gamma \leq 0.9$ is shown in Fig. 4 as a function of E_T^γ and η^γ. Overlaid are the NLO predictions of two groups of theorists, LG [6] and KZ [7], each using two different γ parton density parametrisations: GRV [8] and GS [9]. The predictions are in reasonable agreement with the data, although those based on the GS parametrisation tend to be low. This demonstrates the sensitivity of this type of analysis to the γ parton density. With more data and further theoretical progress the prompt-γ process will provide a valuable tool for studying NLO pQCD and measuring the γ parton density.

§ The ZEUS coordinate system is defined as right-handed with the Z-axis pointing in the forward (proton beam) direction. The origin is at the nominal ep interaction point, and the polar angle θ is defined with respect to the positive Z-direction.

3. Deeply Virtual Compton Scattering

For the DVCS analysis [5], events with only two EM clusters and at most one track (which must be matched to one of the clusters) are selected. The first (second) candidate, corresponding to the scattered e^+ (γ) in the DVCS case, must have polar angle $\theta_1 > 2.8$ ($\theta_2 < 2.4$) radians and $E_1 > 10$ GeV ($E_2 > 2$ GeV). To suppress the QEDC process the polar angle difference must satisfy $|\theta_1 - \theta_2| > 0.8$ radians. Among the remaining requirements are a cut of $Q^2 > 6$ GeV^2, calculated using the first EM candidate, and a cut on the invariant mass of the two EM candidates, $M_{12} < 30$ GeV. From 37pb^{-1} of e^+p data, 1954 events remain for further study after application of all cuts.

As an aid to studying DVCS, a MC generator GenDVCS [10] based on the DVCS, QEDC, and interference term (int) cross sections provided by FFS [2] was developed at ZEUS. Samples of DVCS+QEDC+int events (elastic only) were generated according to the predicted cross sections, run through a full detector and trigger simulation, and processed using the same reconstruction program as the real data. Additional samples were similarly generated using the QEDC generator Compton2.0 [11] (elastic only) for comparison, as well as RAPGAP [12] (diffractive events) and DJANGOH [13] (inclusive DIS events) samples for studying background from π^0/η contamination.

Shown in Fig. 5 is the polar angle distribution of the second EM candidate, θ_2, for (a) all candidates, and (b) only those candidates without a matched track (γ candidates). The third plot (c) shows the ratio of (a) and (b). Overlaid are the predictions from Compton2.0 and GenDVCS, normalised to the same luminosity as the data, based on their calculated cross sections. (The QEDC ratio is unchanged when the inelastic component is included.) There is a clear deficit in the number of small angle γ candidates predicted by the QEDC

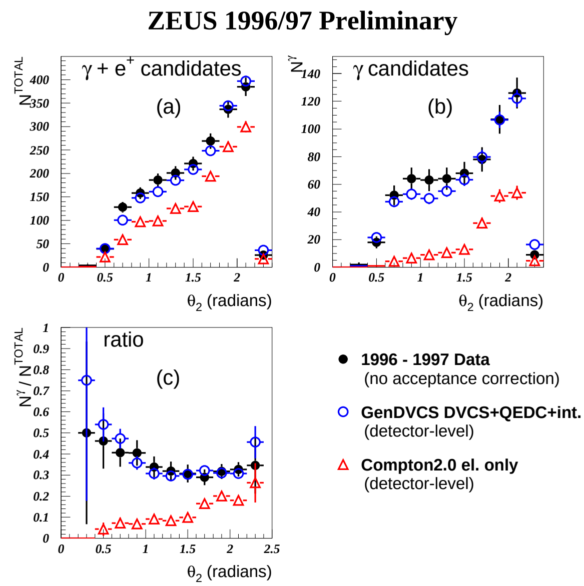

Figure 5. Distribution of θ_2 for the DVCS sample.

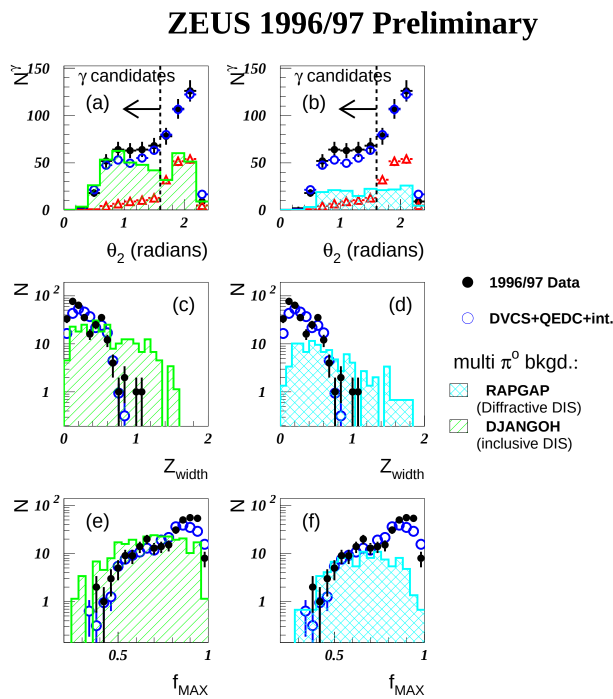

Figure 6. Shower shapes for DVCS γ candidates.

simulation. The inclusion of DVCS brings the prediction into reasonable agreement with the data.

A potential source of background arises from processes like $e^+p \rightarrow e^+\pi^0 p$, etc., where a π^0/η fakes a γ signal in the calorimeter. Redisplayed in Figs. 6(a) and (b) is the θ_2 distribution for γ candidates. Overlaid are the RAPGAP and DJANGOH predictions. It may thus appear possible to explain the data as being due to such events. However, these two generators are not expected to predict accurate rates for low-multiplicity π^0/η production. In fact, as shown in Figs. 6(c)-(f), the Z_{width} and f_{max} distributions for BCAL γ candidates having $\theta_2 < 1.6$ radians, where the QEDC contribution is predicted to be small, indicate that the π^0/η hypotheses cannot account for the EM shower shapes, and so the data cannot be explained as hadronic background from low-multiplicity DIS events. A repetition of the analysis [5] with a harder energy cut ($E_2 >$ 5 GeV) on the second candidate further supports this conclusion. This, then, is first evidence for DVCS at high energy.

4. Acknowledgements

I gratefully acknowledge the many useful discussions about DVCS I have had with A. Freund and M. Strikman. I thank the conveners of my session for their kind and considerate handling of the scheduling of my talk.

References

[1] E. Wieczorek, V.A. Matveev and D. Robaschik, Theoret. Mat. Phys. **19** (1974) 14; J .Bartels and M .Loewe, Z. Phys. **C12** (1982) 263; X. Ji, Phys. Rev. **D55** (1997) 7114; A.V. Radyushkin, Phys. Rev. **D58** (1998) 114008.

[2] L.L. Frankfurt, A. Freund and M. Strikman, Phys. Rev. **D58** (1998) 114001 and Phys. Rev. **D59** (119901E) .

[3] A. Freund, `hep-ph/9903488`.

[4] ZEUS Collab., J. Breitweg *et al.*, Phys. Lett. **B413** (1997) 201.

[5] `www-zeus.desy.de/~schlenst/eps99_paper.html`

[6] L. E. Gordon, Phys. Rev. **D57** (235) 1998.

[7] M. Krawczyk and A. Zembrzuski, `hep-ph/9810253`.

[8] M. Glück, E. Reya and A. Vogt, Phys. Rev. **D46** (1973) 1992.

[9] L. E. Gordon and J. K. Storrow, Nucl. Phys. **B489** (405) 1997.

[10] `www-zeus.desy.de/~saull/public/dvcs.html`.

[11] A. Courau and P. Kessler, Phys. Rev. **D46** (1992) 117.

[12] RAPGAP 2.08/00: H. Jung, Comp. Phys. Commun. **86** (1995) 147 and priv. comm. .

[13] H. Spiesberger, DJANGOH V1.1, 1998, available at `www.desy.de/~hspiesb/djangoh.html`.